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WATER-QUALITY ASSESSMENT OF THE MERCED RIVER, CALIFORNIA, IN THE 1977 WATER YEAR

By Stephen K. Sorenson and Ray J. Hoffman

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-75

Prepared in cooperation with the

CALIFORNIA DEPARTMENT OF WATER RESOURCES

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March 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS, ABBREVIATIONS, AND DEFINITION OF WATER YEAR

The metric system of units is used in this report. For readers who prefer inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply	By	To obtain
cm (centimeter)	0.3937	in (inch)
cm^2 (square centimeter)	0.1550	in^2 (square inch)
ha (hectare)	2.471	acre
hm^3 (cubic hectometer)	811	acre-ft (acre-foot)
km (kilometer)	0.6215	mi (mile)
km^2 (square kilometer)	0.3861	mi^2 (square mile)
L (liter)	0.2642	gal (gallon)
m (meter)	3.281	ft (foot)
m^2 (square meter)	10.76	ft^2 (square foot)
m^3/s (cubic meter per second)	35.31	ft^3/s (cubic foot per second)

Temperature °F = Temperature °C(1.8)+32

Explanation of abbreviations:

g C/m^2 (gram of carbon per square meter)
(mg C/m^2)/d (milligram of carbon per square meter per day)
µg/kg (microgram per kilogram)
µg/L (microgram per liter)
µmho/cm (micromho per centimeter)
mg/L (milligram per liter)
mL (milliliter)
rkm (river kilometer)

Definition of water year:

The 12-month period ending September 30 each year is called the "water year." The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year that ended September 30, 1977, is called the 1977 water year.

WATER-QUALITY ASSESSMENT OF THE MERCED RIVER, CALIFORNIA, IN THE 1977 WATER YEAR

By Septhen K. Sorenson and Ray J. Hoffman

ABSTRACT

Water-quality conditions in the Merced River were sampled four times during the 1977 water year at 12 stations on the river and its major impoundments. Samples taken at the record or near-record low flows of the 1976-77 drought, showed that calcium and bicarbonate were the predominant ions in the water. Inflow of irrigation return water to the river caused a threefold to sevenfold increase in specific conductance between river kilometer 42 and the farthest downstream station at river kilometer 8. During the four sampling periods, the increase in total nitrogen concentrations was twofold to sixfold in that reach. Upstream of kilometer 42, the river was free of apparent water-quality degradation, with the exception of occasional increases in nitrogen and phosphorus. Measurements of primary productivity and phytoplankton in Lake McClure and at three river stations gave indications of trophic conditions in the river system.

INTRODUCTION

The Merced River is one of the major rivers draining the west slope of the Sierra Nevada. It is tributary to the San Joaquin River, which drains the southern half of California's Central Valley. The upper reaches of the Merced River drain Yosemite National Park. Heavy use by visitors of this popular natural area through the year makes it subject to water-quality degradation. Concerns for quality of the Merced River are based on the suitability of the water primarily for irrigation and secondarily for public supply and water sports.

The U.S. Geological Survey conducted two previous studies on the upper reaches of the Merced River (Hoffman, 1979, and Hoffman and others, 1976). The assessment of Merced River quality and the preparation of this report are parts of a cooperative agreement between the U.S. Geological Survey and the California Department of Water Resources. Data from the 1976-77 sampling for this assessment were reported by Hoffman (1978).

The purpose of the study is to describe the quality of the Merced River and its major impoundments over a 1-year hydrologic cycle at stations representative of the entire river. To accomplish this purpose, selected physical, chemical, and biological data were collected seasonally along the river and its major impoundments during the 1977 water year.

DESCRIPTION OF STUDY AREA

Geologic Overview

The Merced River basin (fig. 1) can be divided into three geologic zones. The first, consisting of the upper part of the basin above El Portal at the entrance to Yosemite Valley, is composed mostly of granitic rocks associated with the Sierra Nevada batholith. In Yosemite Valley there are glacial and sedimentary deposits derived from the granitic areas upstream. The second, consisting of the middle reach of the river from El Portal to Merced Falls Dam (western foothills area), is a mixture of metavolcanic (mostly pyroclastic rocks of andesitic composition) and metasedimentary rocks (mostly thin-bedded siltstone) (California Division of Mines and Geology, 1962). The riverbed in the western foothills area, approximately one-third of the length of the river, is mostly black carbonaceous phyllite with interbedded metachert and some areas of limestone and dolomite (California Division of Mines and Geology, 1962). In the third zone, downstream from Merced Falls Dam, the river flows over Tertiary and Quaternary alluvial deposits derived from the Sierra Nevada.

Climate

Climate in the Merced River basin varies widely with elevation. Lower elevations in the San Joaquin Valley and adjacent foothills are characterized by hot, dry summers and mild, wet winters. At higher elevations, mild, dry summers and cold, wet winters with heavy snowfall are typical. Mean annual precipitation varies from approximately 25 cm at lower elevations, to over 114 cm at higher elevations. From 85 to 90 percent of the annual precipitation occurs during the period from November through April. Thunderstorms are frequent at higher elevations during the summer (Anderson and others, 1966).

Land Cover

The California Department of Water Resources constructed land-use and land-cover maps of Mariposa County in 1959 and Merced County in 1974. Interpretation of these maps shows land cover in the Merced River basin as outlined in table 1. Each of the three reaches of the river has a characteristic land cover. The upper reach contains all the bare-rock, heavy-conifer, subalpine, juniper, and lodgepole areas. The middle reach contains most of the light-conifer, brush, chaparral, light-timber, and deciduous-tree areas. The lower reach below Lake McClure is composed of 62.5 percent irrigated cropland and 37.5 percent grassland.

TABLE 1. - Land cover in the Merced River basin

Percentage of total	Land-cover type	Area (square kilometers)
21	Brush, chaparral, light timber	673
17	Light conifers	544
15	Subalpine, juniper, lodgepole	482
15	Deciduous trees	482
13	Irrigated crops	417
8	Heavy conifers	259
7	Grasslands	225
4	Bare rock	127
100		3,209

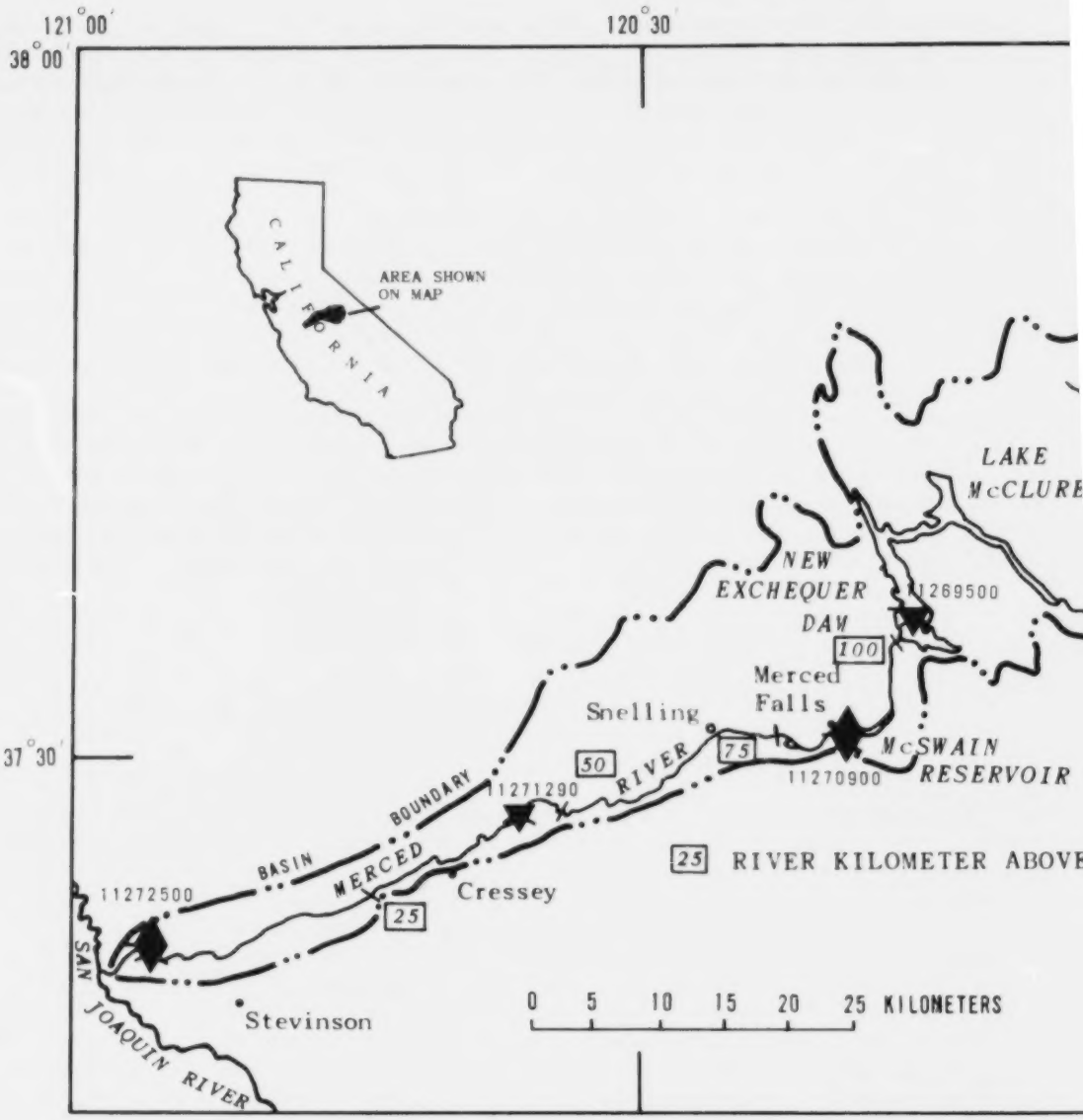

FIGURE 1.—Merced River basin and location of

stations sampled in the 1977 water year.

Merced River

River Channel Description

The Merced River originates on the western slope of Mount Lyell (4,000 m) at the crest of the Sierra Nevada. From its origin to Happy Isles Bridge at the east end of Yosemite Valley (fig. 2), the river descends about 2,400 m in 39 km, an average gradient of 62 m/km. The middle section of this upper reach is impounded by glacial moraines that form Washburn and Merced Lakes. Between these lakes, the river meanders through a swampy meadow for about 3 km. The rest of the upper channel is composed of bare granite, boulders, and a series of waterfalls that includes Vernal Falls and Nevada Falls.

In Yosemite Valley, the river meanders along the flat valley floor. The 11-km-long and 1.6-km-wide valley provides an area for deposition of sediment transported from upstream. In this reach the riverbed is characterized by sand, gravel, and cobbles. Much of the river is shaded by native forest vegetation along the valley floor. Several streams flow into the Merced River along the valley floor.

From the west end of Yosemite Valley downstream to Lake McClure, the river cascades through a narrow, steepsided canyon, descending about 900 m in 69 km, an average gradient of 13 m/km. Along this reach, the riverbed is characterized by cobbles and boulders derived from postglacial outwash. Most of this part of the river is unshaded by vegetation.

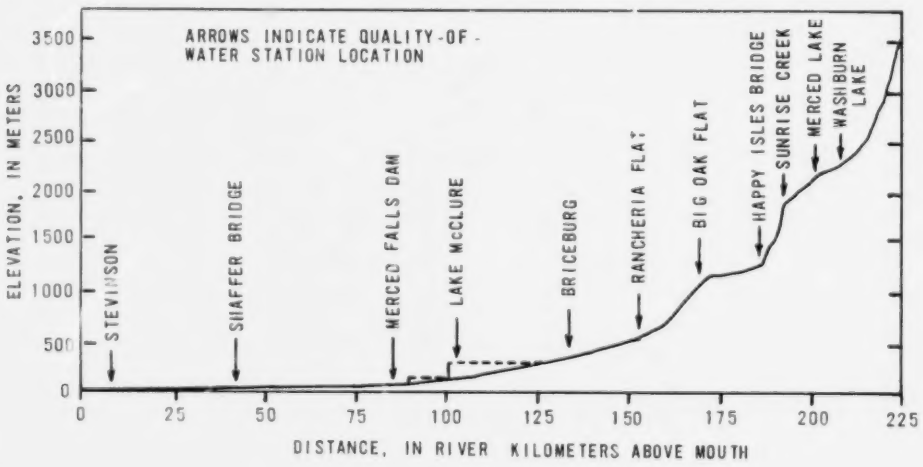

FIGURE 2.—Longitudinal profile of the Merced River channel.

From New Exchequer Dam downstream to the confluence with the San Joaquin River, the Merced River descends about 110 m in 101 km, an average gradient of 1.1 m/km. The riverbed is characterized by sand and gravel upstream from Cressey and is almost exclusively sand and silt downstream from Cressey. The channel near Snelling (rkm 85) has been extensively modified by past and present gravel-mining operations. These operations have created numerous off-stream ponds that are separate from the river during low flow but are a part of the river channel. Numerous oxbow lakes associated with historical river channels are found along the river. Gold-dredging operations have affected the river from about 10 km downstream from Lake McClure. Much of the river downstream from Lake McClure is lined with riparian vegetation that is characteristic of California's Central Valley.

Streamflow

The Merced River upstream from Lake McClure is virtually unregulated by manmade structures. The National Park Service maintains a small diversion dam on the river near rkm 169. This diversion is used to power a hydroelectric plant a few kilometers downstream that provides electrical power to Yosemite National Park. The Merced River's largest tributary, the South Fork Merced River (drainage area, 624 km^2), joins the middle reach at rkm 144. Since January 1977, the middle reach has received secondary-treated effluent from the new Yosemite National Park sewage treatment plant at El Portal.

Exchequer Dam (rkm 101) was built by the Merced Irrigation District in 1926. Enlargement of the dam (renamed New Exchequer Dam) and construction, in 1967, of McSwain Dam, 11 km downstream from Lake McClure, provided a large increase in river water storage capacity. About 2 km downstream from McSwain Dam and about 200 m upstream from the sampling station at Merced River below Merced Falls Dam is a dam that diverts major quantities of Merced River water into the Merced Irrigation District's Main Canal. Downstream from this diversion dam are numerous pumping stations that pump irrigation water directly onto adjoining farmlands. In addition, there are several agricultural return-flow drains that empty waste irrigation water into the river.

The 13-km reach of the Merced River upstream from its confluence with the San Joaquin River may be affected by backwater conditions during periods of high flow in the San Joaquin River (Blodgett and Bertoldi, 1968).

Unregulated runoff is represented by the mean monthly hydrograph for Merced River stations at Happy Isles Bridge (rkm 187) and near Briceburg (rkm 134) (fig. 3). Peak water discharge occurs during the snowmelt period from April through June. Low flow occurs during the period August through February. Hydrographs from Merced River below Merced Falls Dam (rkm 85) and Merced River near Stevinson (rkm 8) are shown in figure 4. Flow at these stations generally followed the pattern of the unregulated station upstream, except that higher base flow was maintained because of water stored in Lake McClure.

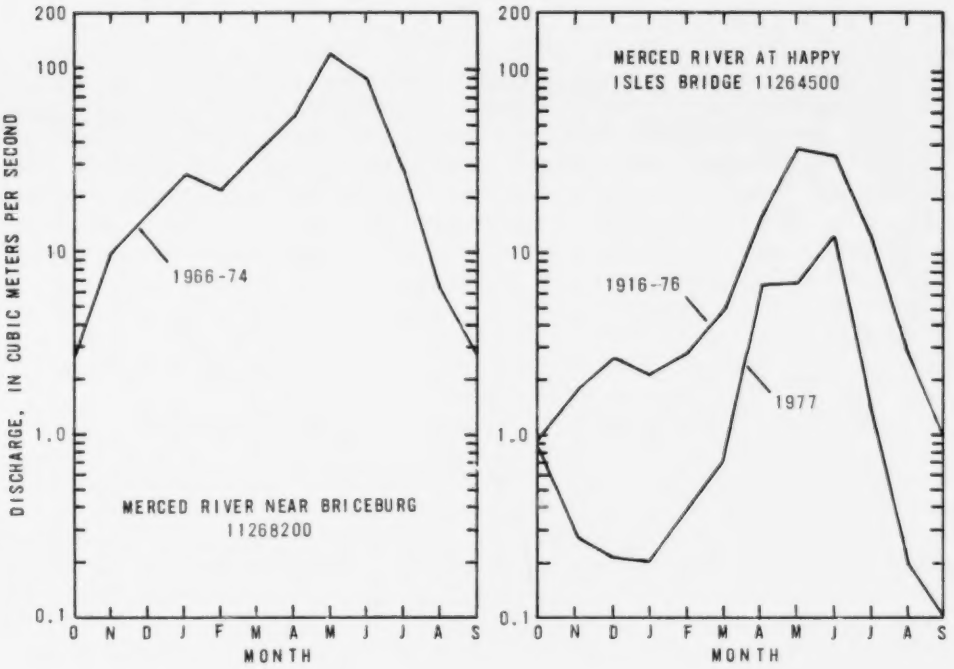

FIGURE 3.—Mean monthly discharge for Merced River stations near Briceburg and at Happy Isles Bridge.

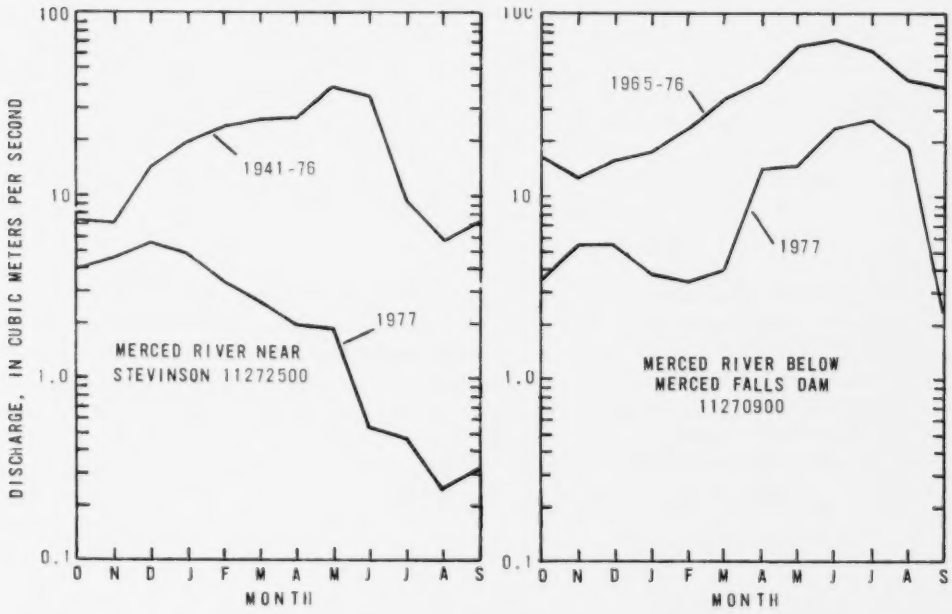

FIGURE 4.—Mean monthly discharge for Merced River stations near Stevinson and below Merced Falls Dam.

There is major pumping of irrigation water in the reach of the river between Merced Falls Dam and Stevinson. Hydrographs indicate that pumpage is highest from June through October. In August 1977, mean flow at Merced Falls Dam, just downstream from Lake McClure, was 18 m^3/s. Irrigation diversions and seepage reduced mean flow to 0.25 m^3/s at Stevinson during this same month.

Hydrographs for the 1977 water year show that flows during the record drought year were considerably below the mean for the period of record. The difference in flows before and during the drought is especially prominent during autumn and early winter when rain usually increases the flow. The hydrograph for Stevinson shows extreme low-flow conditions at the station during June, July, August, and September of 1977.

Flow-duration curves were constructed for three stations on the Merced River (fig. 5). These curves represent the flow duration for 1941-77 at Happy Isles Bridge and near Stevinson and for 1964-77 below Merced Falls Dam. (This station was established in 1964 when the New Exchequer Dam was completed.) The curve for Happy Isles Bridge shows a steep slope indicative of a fast flowing, unregulated stream, with highly seasonal precipitation. The decrease in slope at the top of the curve shows that the river derives much of its flow from snowmelt (Searcy, 1959). The flattening of the curve at the lower end indicates substantial low-flow input from springs and other sources that tend to maintain a relatively constant low flow. The median flow (daily mean flow equaled or exceeded 50 percent of the time) at Happy Isles Bridge was 2.8 m^3/s.

The configuration of the curve at the station below Merced Falls Dam is similar to the one at Happy Isles Bridge. The median flow of 31.2 m^3/s, however, was substantially higher. Because this station is located downstream from the major diversion of release water from Lake McClure, it is subject to flow changes related to the operation of the diversion. This, along with the relatively short period of record, accounts for the slightly irregular shape of the curve.

The flow-duration curve for the Stevinson station is considerably different from those for the other two stations. The flattened slope in the middle indicates a long period of fairly constant flow. Daily flow ranged from 2 to 7 m^3/s more than 50 percent of the time. The median flow at Stevinson was 6.8 m^3/s.

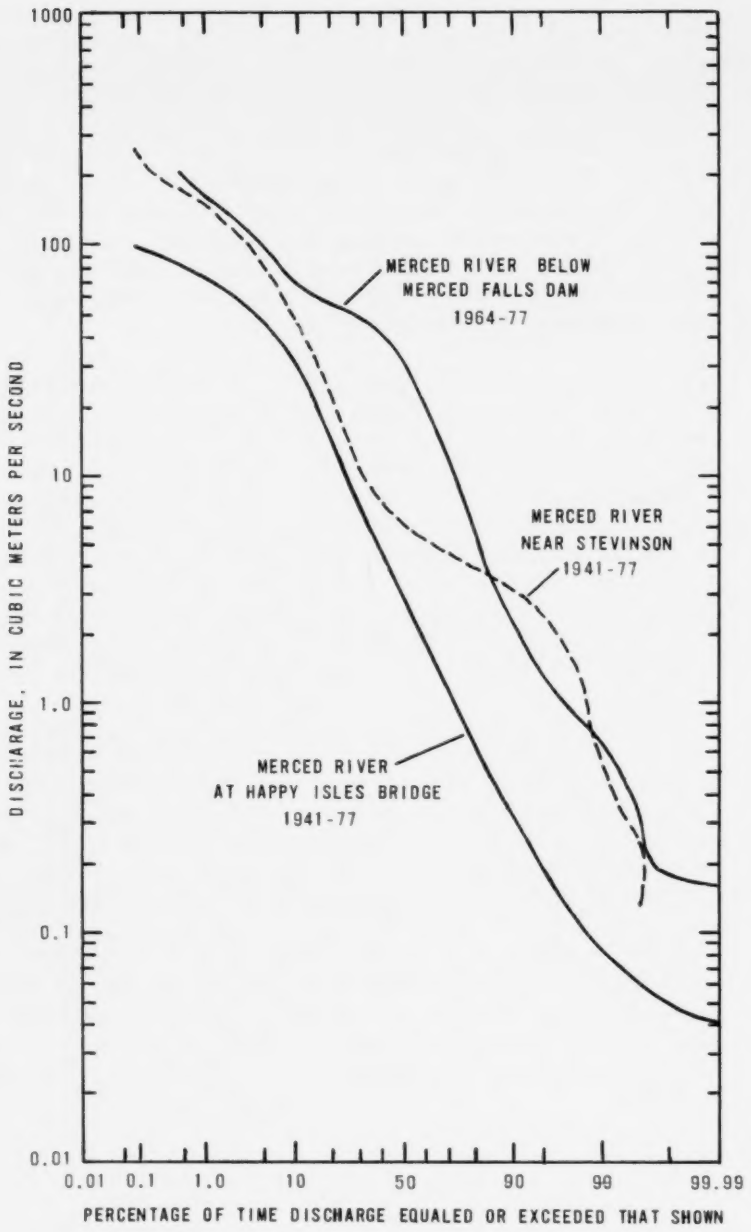

FIGURE 5.—Flow duration curves.

Reservoirs and Lakes

Lake McClure, created by the New Exchequer Dam (rkm 101), has a maximum capacity of 1,264 hm^3 and a spillway elevation of 261 m. Its surface area is 2,884 ha at maximum and averages 546 ha in midsummer. The reservoir is multipurpose, typical of reservoirs in the Sierra Nevada foothills. Its primary function is to store water from periods of high spring runoff for irrigation use by the San Joaquin Valley's extensive agricultural industry. As a result, the reservoir is subject to large seasonal water-level fluctuations. Its maximum capacity is usually reached in May, June, or July, and levels are lowest in September or October. Secondary uses are power generation and recreation.

McSwain Reservoir is a small reservoir created by McSwain Dam, about 13 km downstream from New Exchequer Dam. This reservoir serves as an afterbay for Lake McClure to reregulate releases. No water samples were taken from McSwain Reservoir.

Washburn (rkm 209) and Merced (rkm 203) Lakes on the upper reaches of Merced River are small and shallow, typical of the many high-elevation lakes in the Yosemite region that were formed by glacial deposits. Washburn Lake has a surface area of 21.5 ha and a maximum depth of approximately 20 m. Merced Lake has a surface area of 22 ha and a maximum depth of approximately 21 m.

WATER-QUALITY ASSESSMENT

The 1977 water year sampling program was discussed in detail by Hoffman (1978). Sampling stations used in the 1977 water year are listed in table 2, and their locations are shown in figure 1.

TABLE 2. - Stations sampled in the 1977 water year

[See figure 1 for location of stations]

USGS station No.	Name	River kilometer above mouth	Drainage area (km^2)
11272500	Merced River near Stevinson	8	3297
11271290	Merced River at Shaffer Bridge, near Cressey	42	2893
11270900	Merced River below Merced Falls Dam, near Snelling	85	2748
11269500	Lake McClure at Exchequer	101	2686
11268200	Merced River near Briceburg	134	1790
11267050	Merced River at Rancheria Flat, near El Portal	154	1018
11266750	Merced River at Big Oak Flat, near El Portal	170	894
11264500	Merced River at Happy Isles Bridge, near Yosemite	187	469
374403119302700	Merced River above Sunrise Creek, near Yosemite	193	298
374408119244500	Merced Lake above Echo Creek, near Yosemite	203	189
374257119221500	Washburn Lake above Lewis Creek, near Yosemite	209	109
374240119215800	Merced River above Washburn Lake below Red Peak Fork, near Yosemite	211	104

Merced River

Chemical Characteristics

Dissolved solids

Water quality in the Merced River changes as the river flows from its origins to the San Joaquin River. Figure 6 shows the specific conductance (a reflection of the dissolved-solids concentration) to be increasing downstream during the four sampling periods in the 1977 water year. This increase was particularly evident at the two stations farthest downstream (rkm 8 and 42) where irrigation return water enters the river. The irrigation supplies originate in the Merced River, ground water, and canals bringing water from other rivers. Irrigation return flow characteristically has high specific conductance, and this increases the conductance of the river.

An exception to increasing downstream mineralization was noted in the autumn, winter, and summer sampling periods, when conductance decreased between the Briceburg station (rkm 134) and the Merced Falls Dam station (rkm 85). As a result of the integrating effect of Lake McClure, conductance was nearly constant in all samples at the Merced Falls station.

Major ions

Calcium and bicarbonate were the dominant ions along most of the Merced River. Figures 7, 8, 9, and 10 show, for each collection period, a river profile of relative concentrations of major ions. The middle reach of the river from Big Oak Flat (rkm 170) to Shaffer Bridge contained a predominance of calcium and bicarbonate. The percentage of sodium and potassium generally decreased downstream, and the percentage of magnesium increased. Along the middle reach, the percentage of major anions remained fairly constant, with a slight downstream increase in the percentage of bicarbonate and a decrease in the percentage of chloride.

Ion dominance changed markedly near both ends of the river. At Merced River near Stevinson, the predominant ions were sodium, potassium, calcium, and bicarbonate. The percentage of chloride was greater at the Stevinson station than at the upstream stations at Shaffer Bridge and below Merced Falls Dam.

In addition to the changes in ion dominance (or predominant ions), the specific conductance increased between Shaffer Bridge and Stevinson (fig. 6). A substantial inflow of high-conductance water (containing mostly sodium and chloride) along this reach of the river accounts for the increase.

Calcium and chloride were the dominant ions at the sampling stations at Happy Isles Bridge (rkm 187) and above Sunrise Creek (rkm 193); below Sunrise Creek calcium and bicarbonate became the dominant ions. The sample taken in summer 1977 at the station farthest upstream (rkm 211) was calcium and bicarbonate water similar to the water at the stations below Happy Isles Bridge. The reason for this apparent change in ion dominance is not known.

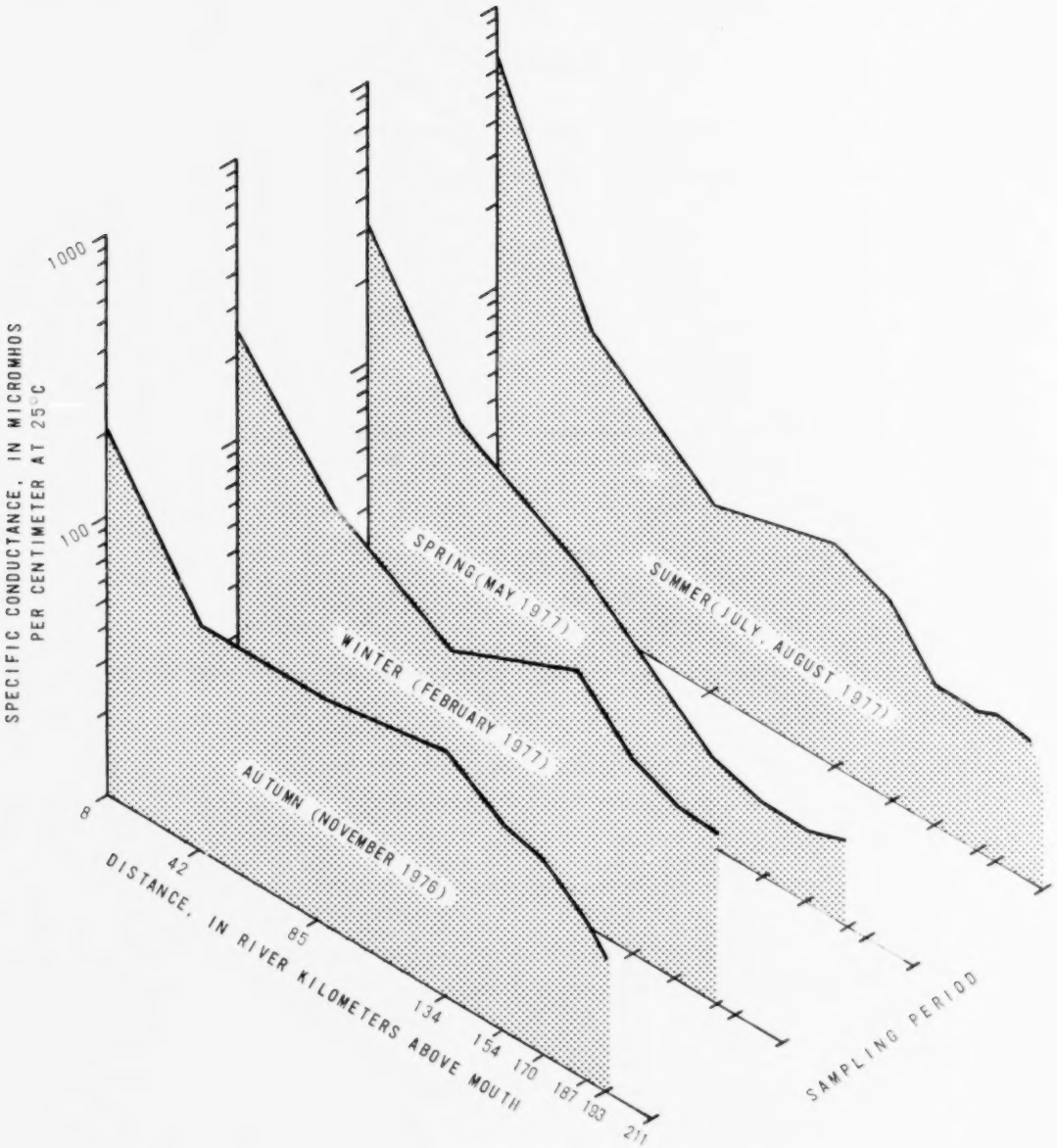

FIGURE 6.—Specific conductance of the Merced River during four sampling periods, 1977 water year.

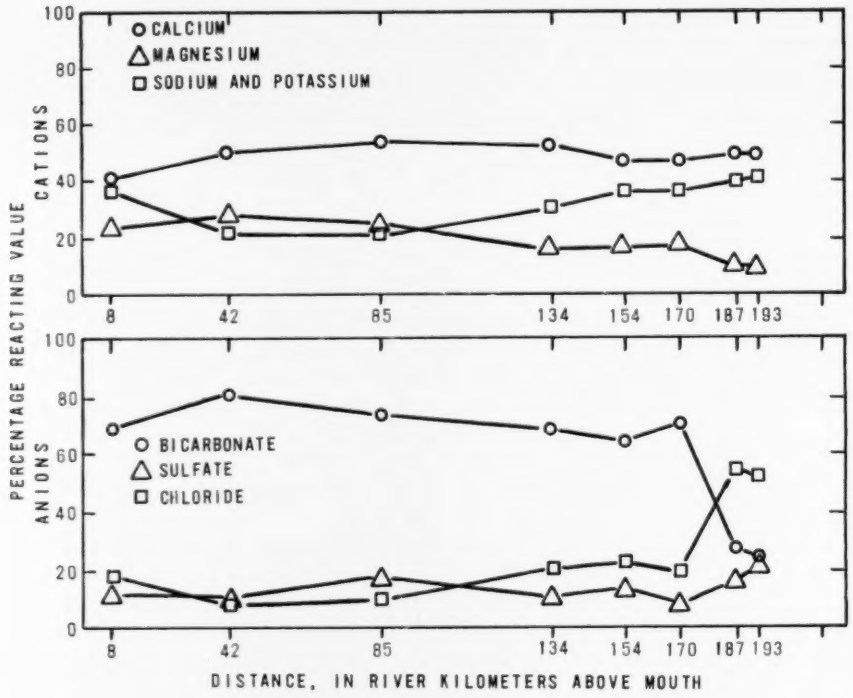

FIGURE 7.—Percentage concentration of major ions in the Merced River, autumn 1976.

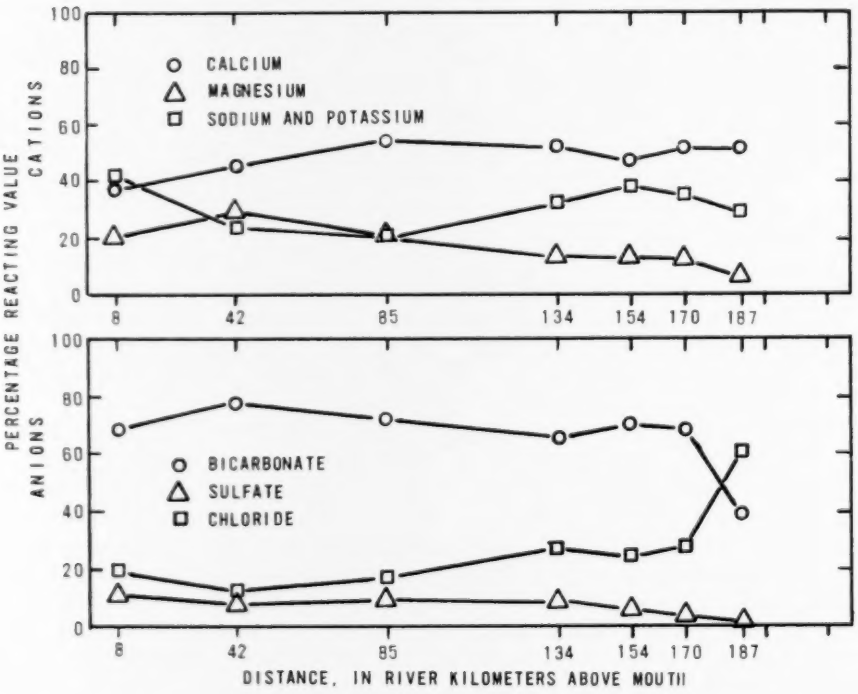

FIGURE 8.—Percentage concentration of major ions in the Merced River, winter 1977.

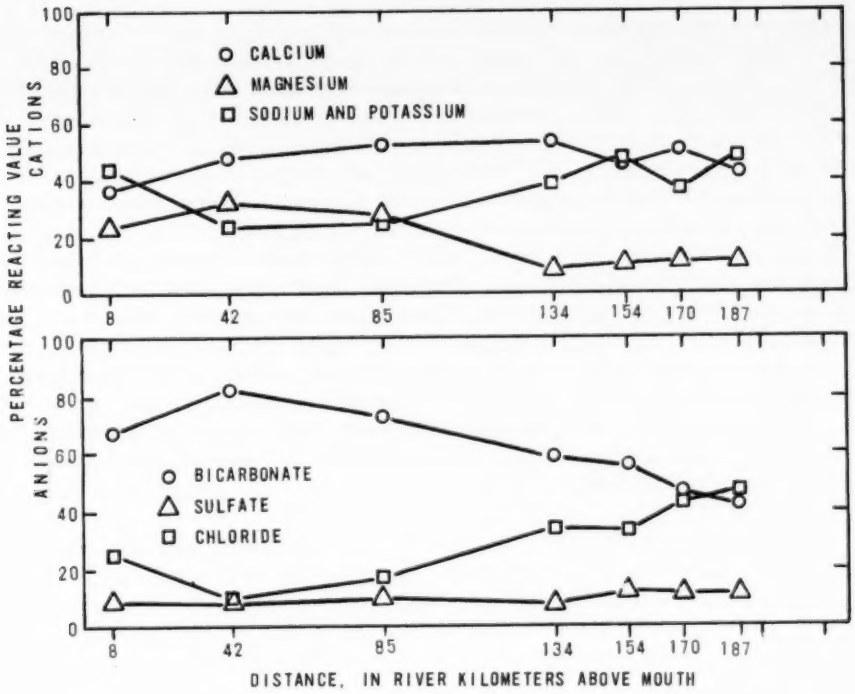

FIGURE 9.—Percentage concentration of major ions in the Merced River, spring 1977.

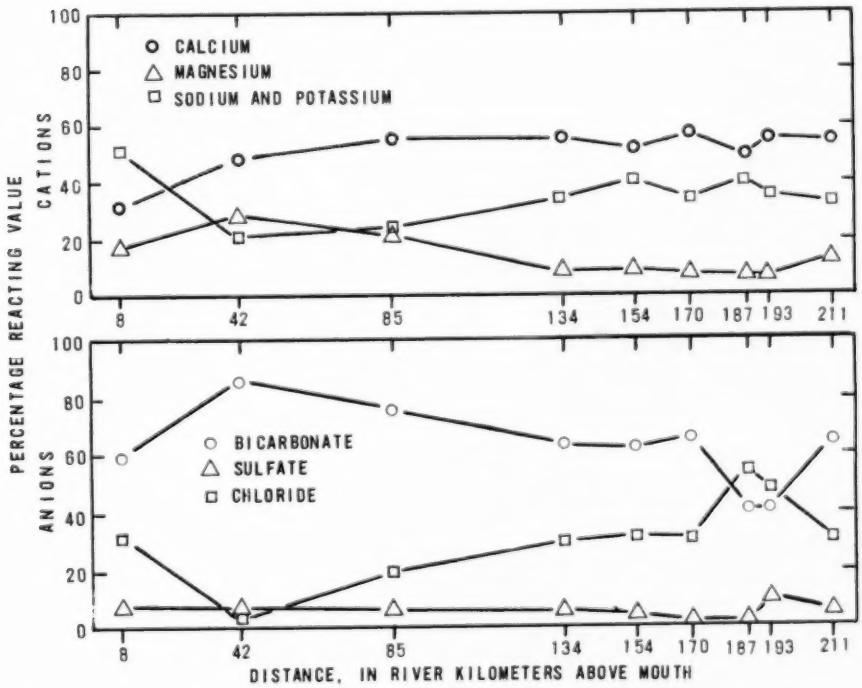

FIGURE 10.—Percentage concentration of major ions in the Merced River, summer 1977.

Nitrogen and phosphorus

Nitrogen and phosphorus are essential plant nutrients commonly found in natural water systems. The concentrations of these nutrients and the chemical forms they take are a major controlling factor in the growth and abundance of phytoplankton, periphyton, and macrophytes. In this study, nitrogen levels generally were below 1 mg/L in the Merced River. Exceptions were the stations near Stevinson in autumn 1976 and winter and spring 1977, and near Briceburg in summer 1977. Figure 11 shows total nitrogen concentrations in the river during four sampling periods. At the two stations farthest downstream, particularly at the Stevinson station, increased concentrations of total nitrogen were composed mostly of the inorganic nitrogen (nitrate), probably reflecting an input of nitrogen with agricultural return water. At the Merced Falls Dam station downstream from the reservoirs, concentrations of total nitrogen were low and nearly constant throughout the year, with a slight decrease apparent from autumn 1976 to summer 1977. The nitrogen at the Merced Falls Dam station was mostly organic nitrogen.

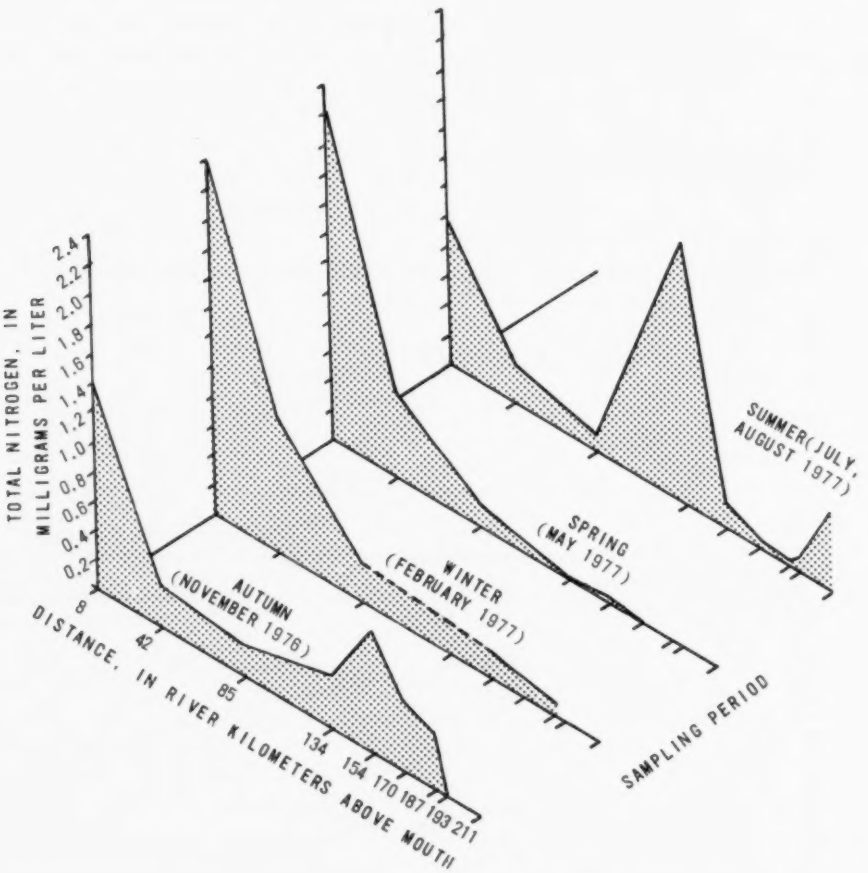

FIGURE 11.—Total nitrogen concentrations in the Merced River during four sampling periods, 1977 water year.

Upstream from Lake McClure, nitrogen concentrations varied considerably with the seasons. During low-flow conditions sampled in autumn and summer, nitrogen concentrations were relatively high at Briceburg and Rancheria Flat (rkm 154) (fig. 11). Of special note was the 1.8 mg/L total nitrogen, mostly in the form of nitrate, at the Briceburg station in summer 1977. The source of this high nitrogen concentration is not known but may have been effluent from the sewage treatment plant at El Portal (Hoffman, 1979). The autumn 1976 sample showed increased total nitrogen concentrations, mostly organic nitrogen, at Happy Isles Bridge, Big Oak Flat, Rancheria Flat, and Briceburg. At the time of the autumn 1976 sample, the El Portal sewage treatment plant was not in service, and effluent was being discharged from the old treatment plant between Happy Isles Bridge and Big Oak Flat.

Of particular interest was the 0.57 mg/L of total nitrogen (mostly organic) found at the station upstream from Washburn Lake during the summer 1977 sampling. Washburn Lake also showed high concentrations (0.55 mg/L) of organic nitrogen in July 1977. Further study is needed to determine the source of this organic nitrogen.

Total phosphorus concentrations were low (0.02 mg/L or less) at all stations and sampling periods except the autumn, winter, and spring collections at Stevinson, the winter and spring collections at Shaffer Bridge, and the autumn collection at Big Oak Flat and Rancheria Flat (fig. 12). The increased levels at the downstream stations were probably due to agricultural

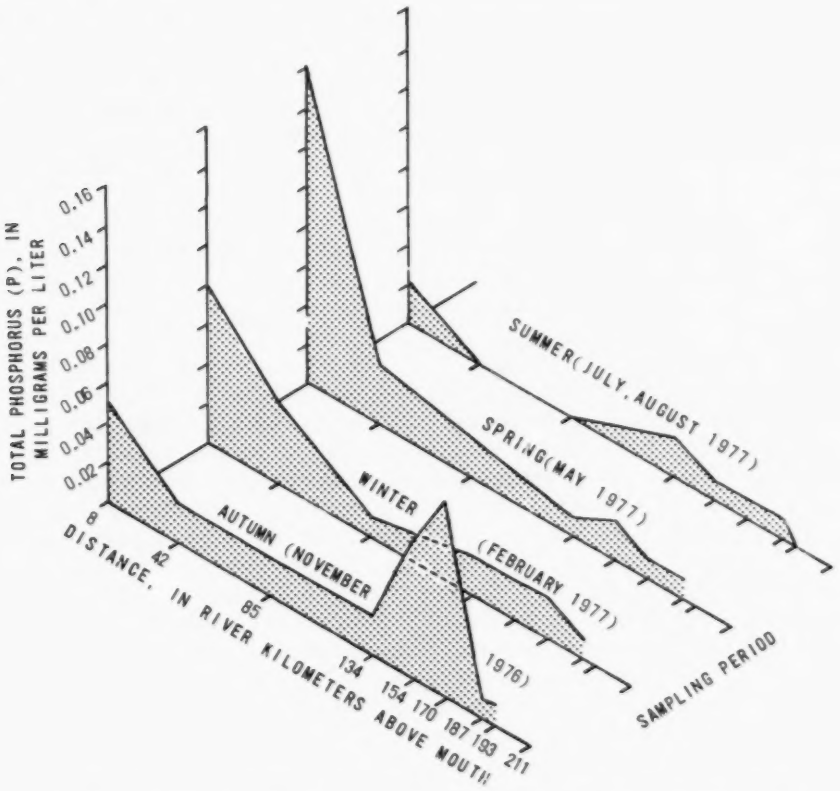

FIGURE 12.—Total phosphorus concentrations in the Merced River during four sampling periods, 1977 water year.

return flow. The source of the higher concentration of phosphorus (mostly orthophosphorus) between Happy Isles Bridge and Big Oak Flat (0.01 and 0.10 mg/L total phosphorus, respectively) is unknown; however, similar increased concentrations of phosphorus had been observed at the Rancheria Flat station during autumn of previous years (Hoffman and others, 1976; and Hoffman, 1979).

Trace elements

Concentrations of trace elements sampled in the Merced River were low, near, and below detection limits with a few exceptions. A 1,200 µg/L concentration of dissolved manganese was detected in the summer sample at the Stevinson station. This concentration exceeds the U.S. Environmental Protection Agency (EPA) Secondary Drinking Water Standards maximum contaminant level of 50 µg/L (EPA, 1977). Mercury concentrations exceeding the EPA (1975) Primary Drinking Water Standards maximum contaminant level of 2 µg/L were found at Merced Falls Dam (4.4 µg/L in the winter sample) and at Happy Isles Bridge (3.2 µg/L in the winter sample). Further sampling is needed to determine the frequency at which concentrations exceed EPA standards and to identify the source of contamination.

Pesticides

Water and sediment samples for pesticide analysis were collected at the Stevinson and Briceburg stations during the spring period of high runoff. The water samples showed no traces of the pesticides tested. Bed-material samples taken in July 1977 showed detectable concentrations of pesticides at the Briceburg station (1 µg/kg PCB) and at the Stevinson station (0.6 µg/kg DDE). The source of these organic compounds is unknown.

Biological Characteristics

Phytoplankton

Phytoplankton cell counts in the Merced River ranged from 48 cells/mL at Happy Isles Bridge in February 1977 to 2,863 cells/mL at Merced Falls Dam, also in February 1977. The cell counts were relatively constant at Happy Isles Bridge (rkm 187), ranging from 48 to 130 cells/mL, and at Briceburg (rkm 134), ranging from 114 to 289 cells/mL, with slightly higher values during the spring and summer. Phytoplankton cell counts at Briceburg were more than double the cell counts at Happy Isles Bridge in all collections except in May, when numbers declined slightly between the two stations. The two stations downstream from Lake McClure that were sampled for phytoplankton had the highest concentrations. The relatively high (448 to 2,863 cells/mL) phytoplankton cell counts at Merced Falls Dam (rkm 85) probably were due to slow-moving water in this section of the river, higher water temperatures, higher nutrient levels, and phytoplankton contributed from Lake McClure. Because phytoplankton populations in Lake McClure were high, large numbers could be expected at the downstream stations.

There was a distinct difference in species composition between samples taken at stations upstream and downstream from Lake McClure. Upstream from the lake, diatoms were the dominant forms, particularly those that have a tendency to be periphytic in nature such as Achnanthes (Smith, 1950). Downstream from the lake, diatoms also dominated, but they were free-floating types such as Navicula, Melosira, and Fragilaria.

Significant numbers of a category of phytoplankton designated miscellaneous flagellates were present in all collections. Further study is needed to identify these organisms and to determine their significance in the river. A more extensive study would be required to clearly understand the seasonal and spatial variations in phytoplankton along the river.

Benthic invertebrates

Benthic invertebrates were both numerous and diverse in the Merced River during 1977 (fig. 13). Results of all collections at each of the four stations sampled indicated an organism density of at least 1,300/m^2, except the February 1977 collection at Stevinson. The largest number of organisms was 5,000/m^2 in the February collection below Merced Falls Dam. At Merced Falls Dam and Happy Isles Bridge, the number of organisms per square meter was greater in February than in July. The opposite was the case at the other two sampling stations. Collections at all sites indicated a greater number of taxa in July than in February. Seasonal differences in numbers and composition of the benthic community could not be determined in detail because of the small number of sampling periods.

Organisms of the order Diptera were the most diverse and numerous in all the collections except in July at Briceburg, where Ephemeroptera (Mayfly nymphs, genus Baetis and Epeorus) was the dominant order and Diptera was second.

Samples from stations upstream from Lake McClure differed distinctly in species composition from downstream samples. Ephemeroptera were more numerous and more diverse at the two upstream stations than at the downstream stations. Coleoptera were present upstream from Lake McClure but not at the two downstream stations. Asiatic clams (Corbicula manilensis) were present at Stevinson and Merced Falls but not at the stations upstream from Lake McClure. The difference between the upstream and downstream stations can be attributed to different river substrates. The upstream stations have a mixed gravel-and-sand substrate, which is preferred by Ephemeroptera and Coleoptera, and the downstream stations have a fine sand-and-silt substrate, which is preferred by asiatic clams.

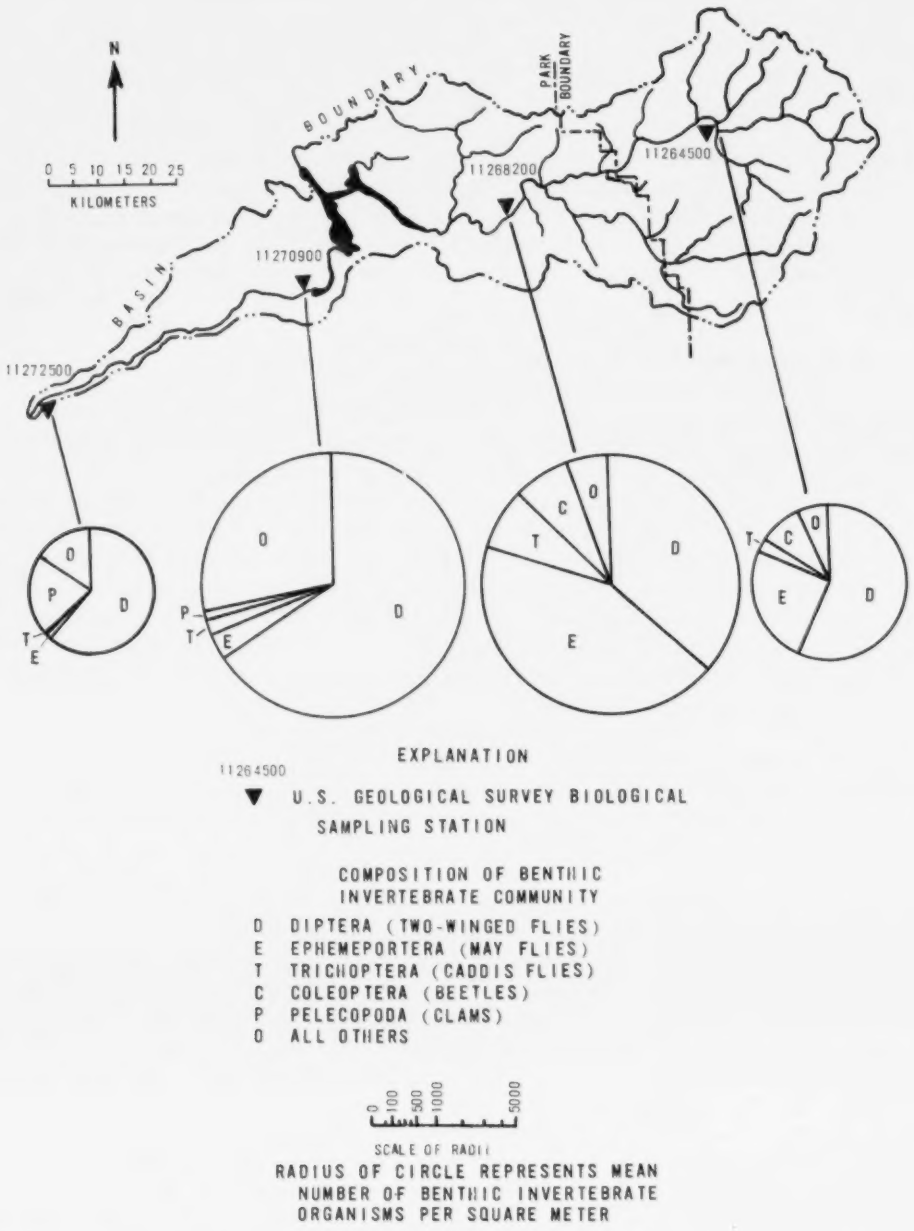

FIGURE 13.—Benthic invertebrate community size (total of two collections) and composition at four stations on the Merced River, 1977 water year.

With the exception of the aquatic Acari and nematodes, which were counted as one genus each, diversity indexes for benthic invertebrates were calculated at the genus level by using the Shannon equation as presented by Wilhm and Dorris (1968) (table 3). The indexes ranged from 2.52 at Stevinson in the February collection to 4.69 at Happy Isles Bridge in the February collection. All indexes were within the range characteristic of clean water (Wilhm, 1970).

TABLE 3. - Shannon diversity indexes for benthic invertebrates

Station name	Collection period	
	February	July
Merced River near Stevinson	2.52	3.44
Merced River below Merced Falls Dam	3.25	3.29
Merced River near Briceburg	4.58	3.26
Merced River at Happy Isles Bridge	4.69	4.18

Diel Measurements

Day-night differences at three stations

Measurements of temperature, specific conductance, dissolved oxygen, and pH were made at three stations over a 24-hour period on August 23 and 24, 1977 (fig. 14). Several aspects of these diel measurements are noteworthy. Temperature variations increased downstream due to less shading from vegetation, increasing ambient temperatures at lower elevations, and attenuation of the effects of snowmelt and springs. Specific conductance varied little over the 24-hour period at the two upstream stations. Specific conductance at the Stevinson station was extremely variable, suggesting that upstream inflows of varying quality entered the river downstream from Lake McClure during the 24-hour study period. Dissolved oxygen became more variable downstream. The largest variation occurred at the Stevinson station, where saturation values ranged from 43 to 224 percent. Dissolved-oxygen saturation varied from 89 to 144 percent at the Briceburg station and was near 100 percent throughout the 24-hour period at Happy Isles Bridge. The observed fluctuations in dissolved oxygen at the two downstream stations were due to respiration and photosynthesis in the plant community. Photosynthesis during the daylight hours produced oxygen supersaturation in the water. At night, community respiration depleted the oxygen faster than it could be replaced from the atmosphere.

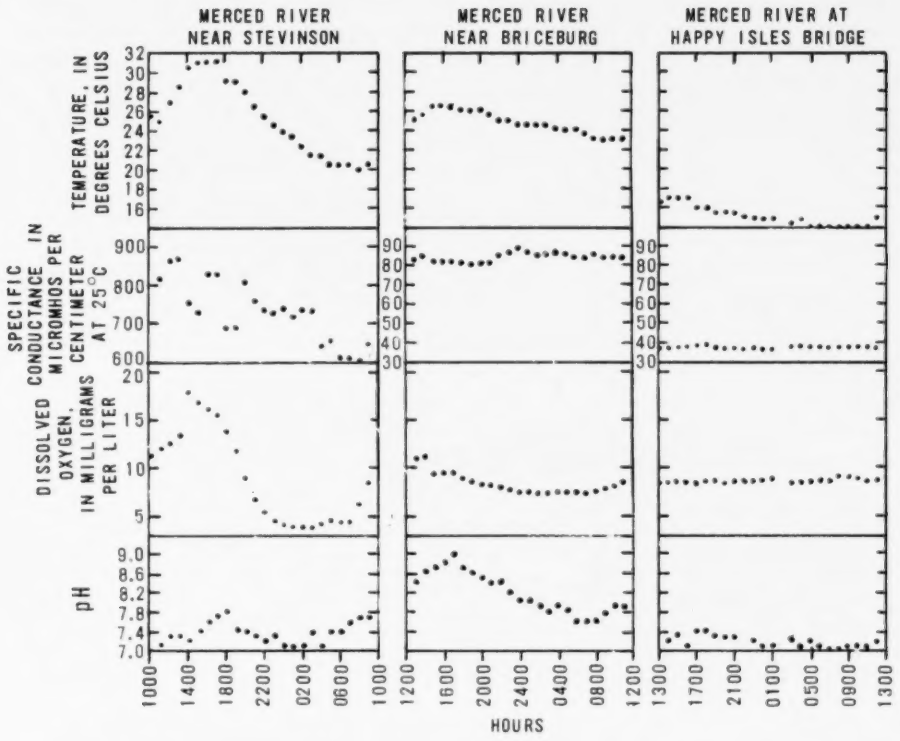
MERCED RIVER NEAR STEVINSON
MERCED RIVER NEAR BRICEBURG
MERCED RIVER AT HAPPY ISLES BRIDGE
TEMPERATURE, IN DEGREES CELSIUS
SPECIFIC CONDUCTANCE IN MICROMHOS PER CENTIMETER AT 25°C
DISSOLVED OXYGEN, IN MILLIGRAMS PER LITER
pH
HOURS

FIGURE 14.—Measurements of temperature, specific conductance, dissolved oxygen, and pH over a 24-hour period, August 23 and 24, 1977.

Primary productivity

Estimates of primary productivity were based on diel oxygen curves obtained for the 24-hour period August 23-24, 1977. Primary productivity was calculated by using the computer program of Stephens and Jennings (1976). The 24-hour community metabolism (primary productivity) was -1.397 g C/m^2 at Happy Isles Bridge, -0.763 g C/m^2 at Briceburg, and 0.885 g C/m^2 at Stevinson. These results show that the Merced River upstream from Lake McClure was a heterotrophic stream (respiration greater than photosynthesis). The river at the Stevinson station was autotrophic (photosynthesis greater than respiration). The net gain in productivity at the Stevinson station was the result of the abundance of phytoplankton, periphyton, and rooted macrophytes, observed in the river at the time of the study, and of the high concentrations of nutrients available to the photosynthesizing organisms.

Lake McClure

Chemical Characteristics

The water in Lake McClure has calcium and bicarbonate as dominant ions and is similar in character to inflow water from the Merced River. With the exception of silica, the dissolved-mineral composition of the lake remained nearly constant throughout the study period and was nearly constant with depth. The concentration of dissolved silica was significantly lower in the August sample than in the other samples. This may be attributed to the large diatom population in the lake during this period because diatoms consume silica to make their shells (Hutchinson, 1957).

Concentrations of nitrogen species in the lake were below 0.1 mg/L, except for organic nitrogen. Organic-nitrogen concentrations were stratified when the lake was thermally stratified and more evenly distributed during winter mixing. The November 1976 sample contained the highest concentrations of organic nitrogen during the study period, ranging from 0.51 mg/L at 1-m depth to 0.84 mg/L at 25-m depth. In February, May, and July 1977, the samples at 1-m depth contained much more organic nitrogen than the samples taken at the same time at 10-m and 25-m depths. The August 1977 sample contained a higher concentration of organic nitrogen (0.62 mg/L) at 10-m depth and lower concentrations (0.15 mg/L and 0.16 mg/L, respectively) at 1-m and 25-m depths.

Vertical profiles of temperature, pH, dissolved oxygen, and specific conductance were made four times during the year in the deepest part of the reservoir near the dam. Profiles of dissolved-oxygen concentration, percent saturation, and temperature (fig. 15) show that the reservoir can be classified as a warm, monomictic lake (Reid and Wood, 1976), stratifying thermally during the summer months and turning over during the winter months. The May profile shows the start of a thermally stratified condition. The August profile shows a more developed metalimnion at approximately 5- to 15-m depth. The oxygen profile indicates a negative heterograde curve (Hutchinson, 1957) with reduced percent saturation of oxygen in the metalimnion. This area of reduced dissolved oxygen corresponds with the 0.62 mg/L of organic nitrogen found at that depth, indicating an area of accumulation and decomposition of organic material. The entire water column warmed up between the May and August sampling periods, but the thermally stratified condition persisted throughout the summer and autumn until November. The February profile shows the lake in a nearly thermally uniform condition that is characteristic of the winter turnover period.

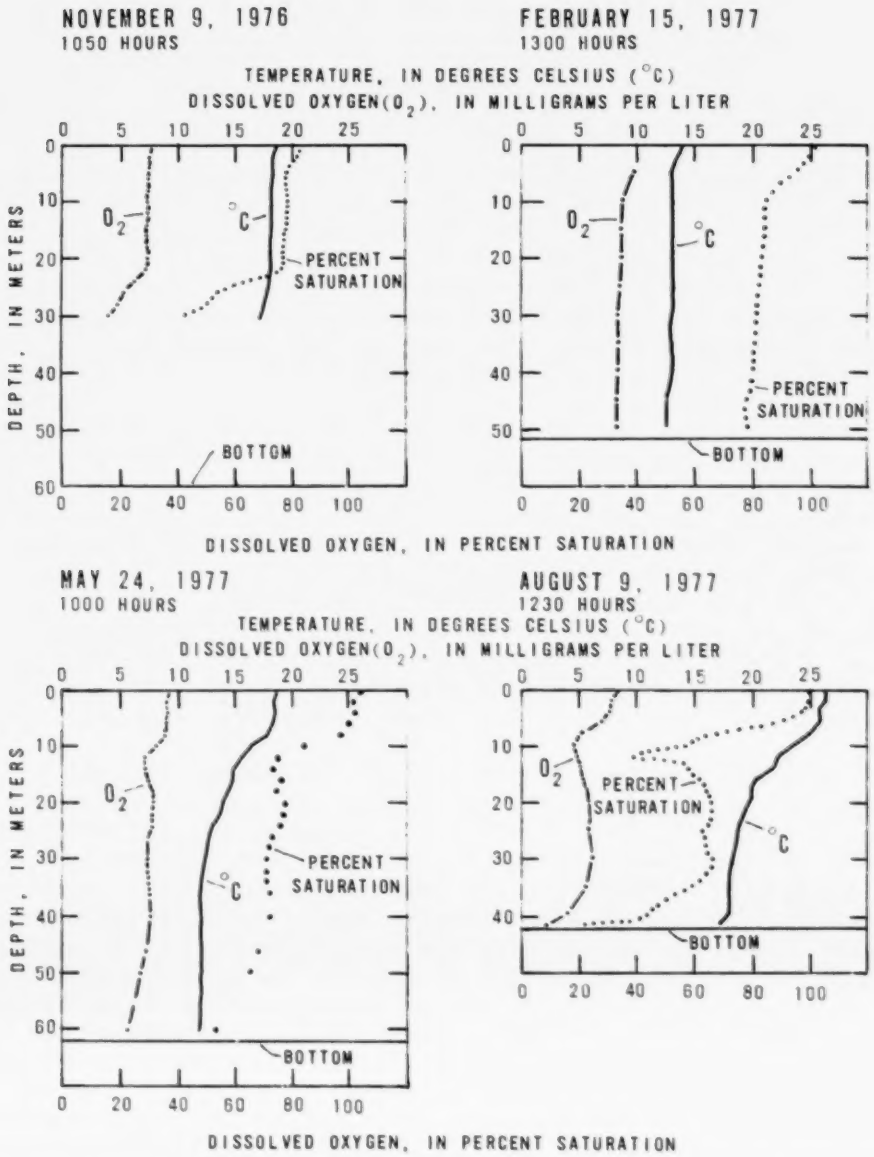

FIGURE 15.—Vertical profiles of temperature, and dissolved-oxygen concentration and percent saturation in Lake McClure, 1977 water year.

Biological Characteristics

Phytoplankton

Phytoplankton samples were collected near the dam five times during the 1977 water year at two or three depths each time. The sampling program was not extensive enough spatially or temporally to characterize the phytoplankton population in Lake McClure. Observations made based on these data, therefore, may not apply to the entire lake during the entire year. The November and August collections, with 2,800 and 3,100 cells/mL, respectively, at 1-m depth, contained the largest concentrations of phytoplankton. During thermal stratification, phytoplankton concentrations were 7 to 20 times greater at 1-m depth than at 10-, 25-, or 50-m depths. The November and February collections, taken when the lake was not thermally stratified, indicated a more even vertical distribution of phytoplankton. In all collections, however, the greatest concentrations of phytoplankton were at the 1-m depth.

Diatoms were the most abundant and diverse group in all collections except in July when Cyanophyta (blue-green algae) were dominant, comprising 46 percent of the total phytoplankton community. Blue-green algae were completely absent from the November and February collections. The percentage of Chlorophyta (green algae) was not large in any of the collections. Cryptophyta (cryptomonads) were found in significant numbers during all collection periods, but only at the 1-m depth during the times of thermal stratification. Miscellaneous flagellates were found in significant numbers in all samples except the November sample at the 50-m depth. The numbers of phytoplankton per milliliter at the 1-m depth and the percentages of major groups are shown in figure 16. Although there was a greater percentage of blue-green algae than other groups in the July collection, the total number of cells per milliliter was much smaller than the numbers typically associated with blue-green algal blooms (Hutchinson, 1957).

The community of phytoplankton found in a body of water can assist in the determination of its trophic state. Hutchinson (1967, p. 384-389) described phytoplankton communities associated with different trophic states. Blue-green algae are common organisms usually associated with eutrophic bodies of water. Although Lake McClure has not been subject to large algal blooms (personal communication with local residents), the July 1977 sample showed that the blue-green algae can be a dominant part of the phytoplankton community. Hutchinson also described a characteristic diatom community found in eutrophic water bodies. This community included *Melosira granulata*, the dominant diatom in the July and August collections and second only to *M. italica* in the November and February collections. The dominant diatom in the May collection was *Fragilaria crotonensis*, another member of Hutchinson's eutrophic diatom community. Community classifications as indicators of trophic conditions vary somewhat, depending on the locality of the lake and the author of the report. Rawson (1956) reported that in lakes of western Canada, *F. crotonensis* and a few genera of blue-green algae also found in Lake McClure were typical of mesotrophic lakes, a classification not mentioned by Hutchinson. Rawson also reported that *M. granulata* are characteristic of oligotrophic lakes. This species was classified as part of eutrophic diatom communities by Hutchinson.

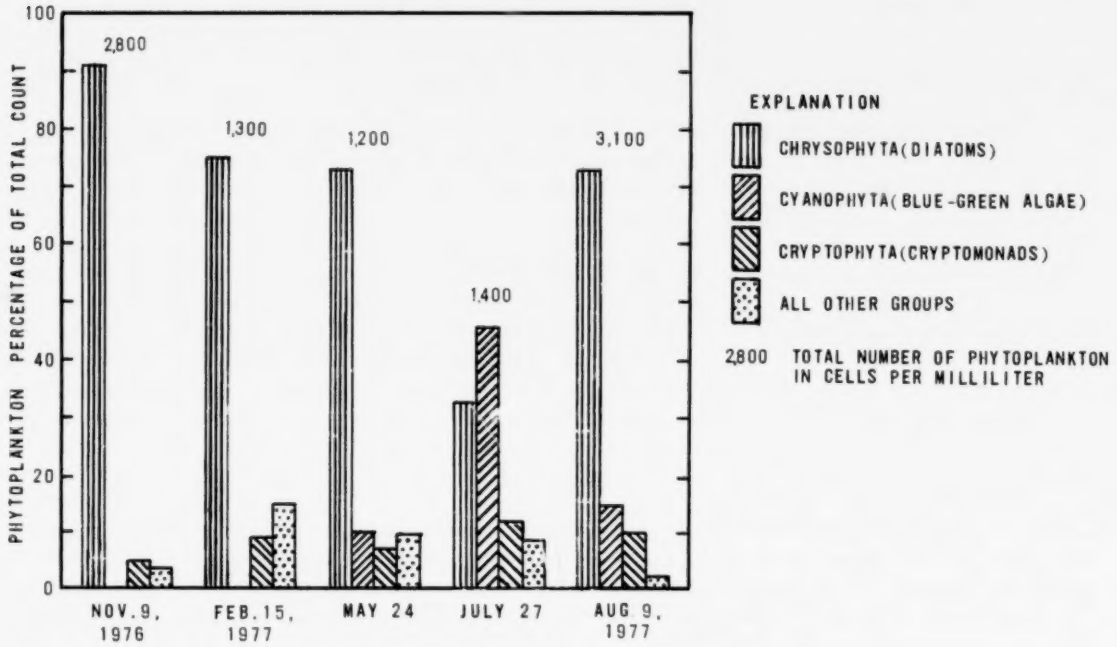

FIGURE 16.—Percentage composition of major groups of phytoplankton in Lake McClure, at 1-meter depth, 1977 water year.

Primary productivity

Primary productivity was measured in Lake McClure on August 9, 1977, by using the carbon-14, light-dark bottle method (Greeson and others, 1977, p. 253-261). At the time of measurement, phytoplankton collections indicated that a diatom bloom was occurring, the principal organism being Melosira granulata. A secchi-disc reading of 0.75 m was observed. Productivity was measured at 200 (mg C/m^2)/d. Eighty percent of the productivity occurred in the 2-m euphotic zone. The value 200 (mg C/m^2)/d classifies Lake McClure as a mesotrophic lake, according to Vollenweider (1970). One measurement of primary productivity is not enough, however, to characterize the trophic state of the lake.

Washburn and Merced Lakes

Washburn and Merced Lakes (rkm 209 and 203) were sampled in August 1977. Merced Lake was also sampled in November 1976. Owing to the difficult accessibility of the lakes, seasonal sampling was not possible. Washburn Lake had calcium and bicarbonate as the dominant ions. Its specific conductance in August 1977 was 16 µmho, less than half the conductance of the inflowing stream. The total organic-nitrogen concentration of 0.55 mg/L was the highest observed at any station except Stevinson (rkm 8) and Lake McClure. It was similar to the total organic-nitrogen concentration of 0.52 mg/L in the inflowing stream.

Washburn Lake was thermally stratified in August (fig. 17). Dissolved-oxygen concentrations were nearly constant from top to bottom except for a decrease just above the bottom.

Phytoplankton cell counts were higher in Washburn Lake than at any other station upstream from Briceburg (rkm 134), probably because of the relatively high nitrogen concentrations in the lake. Phytoplankton numbers in the inflowing stream were similar to those in the lake.

The dominant ions in Merced Lake were calcium, bicarbonate, and chloride in November 1976 and calcium, chloride, and bicarbonate in August 1977. Specific conductance was nearly double that of Washburn Lake during the same sampling period. The concentration of total organic nitrogen was 0.04 mg/L (erroneously reported as 10 mg/L by Hoffman in 1978), which was considerably below the levels found in Washburn Lake.

Temperature and dissolved-oxygen profiles varied little with depth in November, indicating that Merced Lake was mixing at that time. The profile in August showed a thermally stratified condition with some reduction in dissolved oxygen with depth.

In August, phytoplankton concentrations in Merced Lake were lower than in Washburn Lake but higher than at the next two stations downstream. The November phytoplankton cell count was 8 cells/mL, the lowest phytoplankton concentration observed during the 1977 water year sampling program.

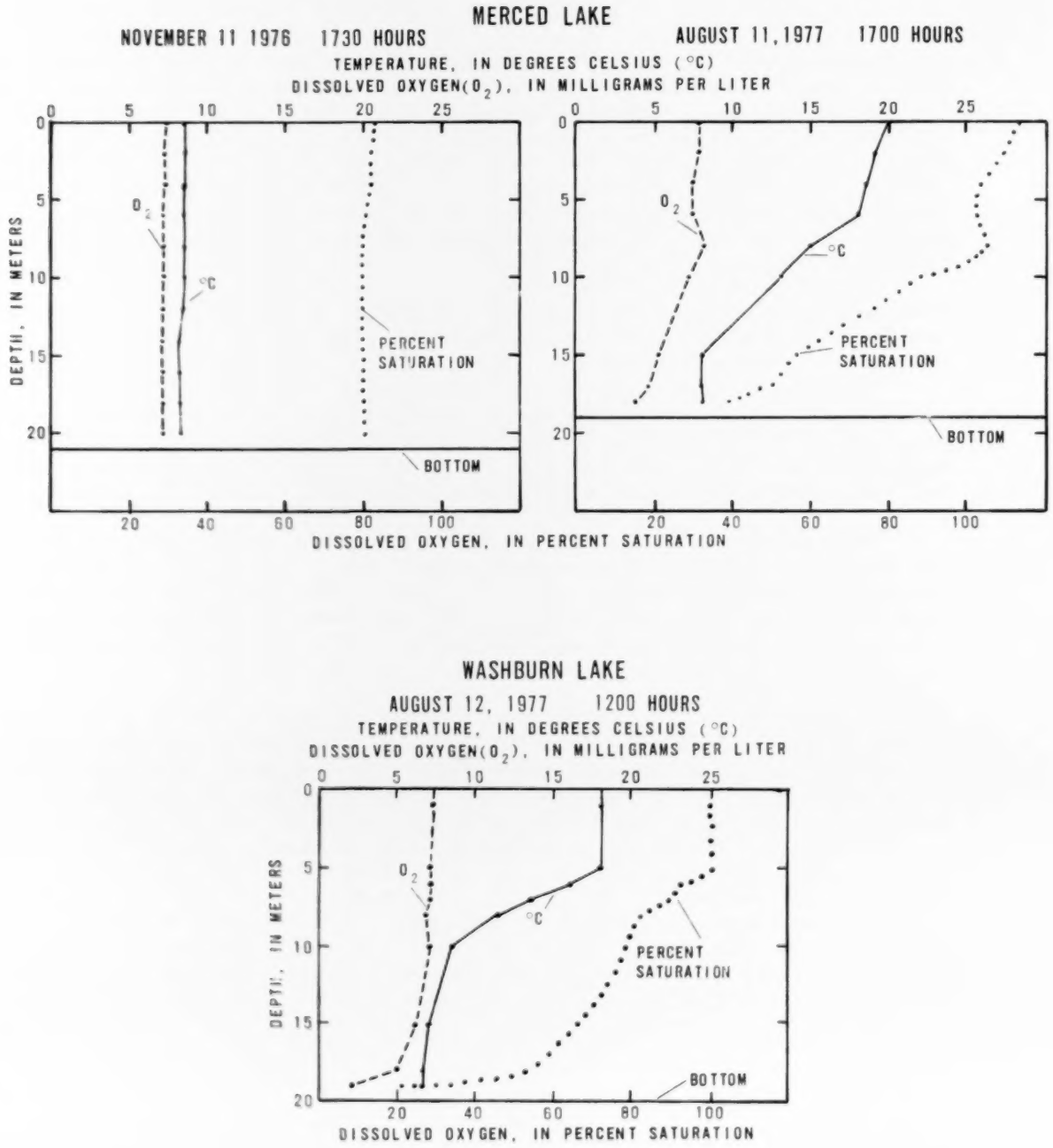

FIGURE 17.—Vertical profiles of temperature, and dissolved-oxygen concentration and percent saturation in Merced and Washburn Lakes, 1977 water year.

SUMMARY AND CONCLUSIONS

The Merced River carries large quantities of water containing predominantly calcium and bicarbonate ions into the Central Valley where the water is utilized mostly for irrigation. The upstream parts of the river are a pristine watershed providing water to areas popular to visitors in Yosemite National Park. After passing from the park, the river is impounded to form two reservoirs that store water at high flows for release during dry seasons. Downstream from its major impoundments, the river is extensively manipulated by diversions, channel alterations, and pumping operations for irrigation.

This study was designed to investigate the quality of water in the river during a 1-year cycle. Water year 1977 was unusual, being a year of record drought immediately following a very dry year. As a result of this 2-year drought, water-supply conditions during the study were not typical of a normal year. This study did, however, provide the opportunity to observe the river under conditions of maximum stress that could have accentuated any water-quality degradations in the drainage basin.

The major findings of the 1977 sampling program were:

1. Concentrations of major inorganic constituents increased downstream.

2. Water in the river generally contained a predominance of calcium and bicarbonate at all stations except near Happy Isles Bridge (rkm 187) and above Sunrise Creek (rkm 193), where it contained calcium and chloride, and near Stevinson (rkm 8), where it contained sodium, potassium, and bicarbonate in three of the four collections.

3. Nitrogen and phosphorus concentrations were generally low except at the station near Stevinson, where total nitrogen concentrations ranged from 0.97 to 2.4 mg/L, and at Briceburg with 1.8 mg/L in the summer collection.

4. Diatoms were the predominant form of phytoplankton in the river.

5. Diel studies indicated little fluctuation in dissolved oxygen, temperature, pH, and specific conductance at the upstream stations, with much greater variations in these measurements at the station farthest downstream, near Stevinson.

6. Primary productivity, as measured by diel dissolved-oxygen curves, showed that the river was heterotrophic (net loss in productivity) during studies at the upstream stations and autotrophic (net gain in productivity) at the Stevinson station.

7. Little seasonal fluctuation in the chemical quality of the water occurred in Lake McClure.

8. Vertical profiles of temperature and dissolved oxygen indicate that Lake McClure is a warm monomictic lake.

This study shows that water in the Merced River is generally of good quality. Along most of its length, no serious water-quality degradations were observed that would adversely affect irrigation--the principal use of the river. In the lower reach of the river, however, concentrations of dissolved solids and nutrients increased substantially, primarily from irrigation return flow. As a result, water of substantially lower quality flowed into the San Joaquin River than was provided by the upstream watershed. Another potential problem identified was the high nitrogen concentrations in the middle reach of the river above Lake McClure. Further study is required to determine the source and extent of the nitrogen and the controls needed to avoid excessive enrichment of Lake McClure.

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